

Fluctuation Effects on R_{pA} at High Energy

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Abstract. We discuss a new physical phenomenon for R_{pA} in the fixed coupling case, the total gluon shadowing, which arises due to the effect of gluon number fluctuations.

We study the ratio of the unintegrated gluon distribution of a nucleus $h_A(k_\perp, Y)$ over the unintegrated gluon distribution of a proton $h_p(k_\perp, Y)$ scaled up by $A^{1/3}$

$$R_{pA} = \frac{h_A(k_\perp, Y)}{A^{1/3} h_p(k_\perp, Y)}. \quad (1)$$

This ratio is a measure of the number of particles produced in a proton-nucleus collision versus the number of particles in proton-proton collisions times the number of collisions. The transverse momentum of gluons is denoted by k_\perp and the rapidity variable by Y .

In the geometric scaling region shown in Fig. 1a the small- x physics is reasonably described by the BK-equation which emerges in the mean field approximation. Using the BK-equation one finds in the geometric scaling regime in the fixed coupling case that the shape of the unintegrated gluon distribution of the nucleus and proton as a function of k_\perp is preserved with increasing Y , because of the geometric scaling behaviour $h_{p,A}(k_\perp, Y) = h_{p,A}(k_\perp^2/Q_s^2(Y))$, and therefore the leading contribution to the ratio R_{pA} is k_\perp and Y independent, scaling with the atomic number A as $R_{pA} = 1/A^{1/3(1-\gamma_0)}$, where $\gamma_0 = 0.6275$ [1]. This means that gluons inside the nucleus and proton are somewhat shadowed since $h_A/h_p = A^{\gamma_0/3}$ lies between total ($h_A/h_p = 1$) and zero ($h_A/h_p = A^{1/3}$) gluon shadowing. The *partial gluon shadowing* comes from the anomalous behaviour of the unintegrated gluon distributions which stems from the BFKL evolution.

We have recently shown [3] that the behaviour of R_{pA} as a function of k_\perp and Y in the fixed coupling case is completely changed because of the effects of gluon number fluctuations or Pomeron loops at high rapidity. According to [5] the influence of fluctuations on the unintegrated gluon distribution is as follows: Starting with an initial gluon distribution of the nucleus/proton at zero rapidity, the stochastic evolution generates an ensemble of distributions at rapidity Y , where the individual distributions seen by a probe typically have different saturation momenta and correspond to different events in an experiment. To include gluon number fluctuations one has to average over all individual events, $h_{p,A}^{fluc.}(k_\perp, Y) = \langle h_{p,A}(k_\perp, Y) \rangle$, with $h_{p,A}(k_\perp, Y)$ the distribution for a single event. The main consequence of fluctuations is the replacement of the geometric scaling by a new scaling, the diffusive scaling [4, 5], $\langle h_{p,A}(k_\perp, Y) \rangle =$

$h_{p,A}(\ln(k_\perp^2/\langle Q_s(Y) \rangle^2))/[DY]$. The diffusive scaling, see Fig. 1a, sets in when the dispersion of the different events is large, $\sigma^2 = \langle \rho_s(Y)^2 \rangle - \langle \rho_s(Y) \rangle^2 = DY \gg 1$, i.e., $Y \gg Y_{DS} = 1/D$, where $\rho_s(Y) = \ln(Q_s^2(Y)/k_0^2)$ and D is the diffusion coefficient, and is valid in the region $\sigma \ll \ln(k_\perp^2/\langle Q_s(Y) \rangle^2) \ll \gamma_0 \sigma^2$. The new scaling means that the shape of the unintegrated gluon distribution of the nucleus/proton becomes flatter and flatter with increasing rapidity Y , in contrast to the preserved shape in the geometric scaling regime. This is the reason why the ratio in the diffusive scaling regime [3]

$$R_{pA}(k_\perp, Y) \simeq \frac{1}{A^{\frac{1}{3}(1-\frac{\ln A^{1/3}}{2\sigma^2})}} \left[\frac{k_\perp^2}{\langle Q_s(A, Y) \rangle^2} \right]^{\frac{\ln A^{1/3}}{\sigma^2}} \quad (2)$$

yields *total gluon shadowing*, $R_{pA} = 1/A^{1/3}$, at asymptotic rapidity Y (at fixed A). This result is universal since it does not depend on the initial conditions. Moreover the slope of R_{pA} as a function of k_\perp decreases with increasing Y . The qualitative behaviour of R_{pA} at fixed α_s due to fluctuation effects is shown in Fig. 1b.

The above effects of fluctuations on R_{pA} are valid in the fixed coupling case and at very large energy. It isn't clear yet whether the energy at LHC is high enough for them to become important. Moreover, in the case where fluctuation effects are neglected but the coupling is allowed to run, a similar behaviour for R_{pA} is obtained [2], including the total gluon shadowing. It remains for the future to be clarified how important fluctuation or running coupling effects are at given energy windows, e.g., at LHC energy.

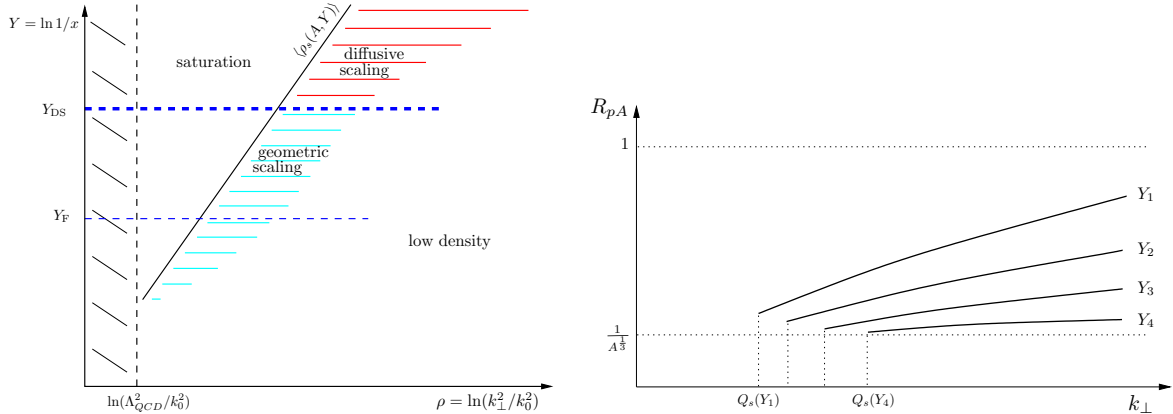


Figure 1. (a) Phase diagram of a highly evolved nucleus/proton. (b) $R_{p,A}$ versus k_\perp at different rapidities $Y_4 \gg Y_3 \gg Y_2 \gg Y_1$.

References

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